Calculating Energy Usage and Savings

APPA Institute for Facilities Management
September 9, 2019
Nashville, TN

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Today's Presentation

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Today's Presentation

Course Description:

This course explores International Performance Measurement and Verification Protocol (IPMVP) options for assessing energy conservation opportunity savings. We describe the IPMVP metering and verification (M&V) methods used for each option, under what circumstances they can/should be applied and offer examples of each.

Learning Objectives:

1. Learn about different IPMVP options
2. Learn about quantifying measures
3. Learn how this information is useful to those who work in business and finance
4. Learn how this information relates to utility billing, calculating conservation program payback and performance contracting.

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WORDS OF WISDOM

"It is really just as bad to make a measurement more accurate than is necessary as it is to make it not accurate enough."

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Agenda

- Overview
  - –Definitions
  - –Basic Options
- Description of M & V Options
- Examples

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IPMVP*

*International Performance Measurement and Verification Protocol

The IPMVP

- Is a framework of definitions and methods for assessing energy savings
- Was designed to allow users to develop a M&V plan for specific projects using the framework of definitions
- Was written to allow maximum flexibility in creating M&V plans that meet the needs of individual projects, but also adhere to the principles of accuracy, transparency and repeatability
- Is policy neutral

Does not cover

- Program evaluation (M&V is about project evaluation - which can be part of a program evaluation)
- Operations and maintenance or demand response
- Determining net savings
- Sample (site) selection for impact evaluation
- Design of meter and instrumentation systems
- Cost estimating of M&V activities

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IPMVP Summary of Options

- The IPMVP has four M&V options: Options A, B, C, and D
- The options are generic M&V approaches for determining energy savings from projects
- Four options provide a range of approaches to determining energy cost avoidance, depending on the characteristics of the energy efficiency projects being implemented, and balancing accuracy in reporting with the cost of conducting M&V.

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Impact Evaluation Concepts

- Impact evaluations are used for determining directly achieved program benefits (e.g., energy and demand savings, co-benefits)
- Savings cannot be directly measured, only indirectly determined by comparing energy use after a program is implemented to what would have been consumed had the program not been implemented (i.e., the baseline)

– Evaluation attempts to measure "what did not happen."

$$\text{Impact} = \text{Actual}_{post} - \text{Projected}_{pre} \pm \text{Adjustments}$$

– It is an estimate, with uncertainty, thus fundamental questions are:

- How good is good enough?
- Compared to what?

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Option A | Option B | Option C | Option D

IPMVP M&V Options

- Option A - Retrofit Isolation: Key Parameter Measurement
  Savings are determined by field measurement of the key performance parameter(s). Parameters(s) which are not measured are estimated. Estimated parameter(s) are based on engineering judgment, analysis of historical data, or manufacturer's data.
- Option B – Retrofit Isolation: All Parameter Measurement
  Builds upon Option A through the use of short-term or continuous metering of all major parameters. Savings are determined with engineering calculations using measured data
- Option C -- Whole Facility
  Determine savings by examining overall energy use in a facility and identifying the impact of measures on total building or facility energy use. Requires comparison of facility-wide meters (typically utility meter) data before and after project installation.
- Option D – Calibrated Simulation
  Involves the use of software to create a model of a facility and its components and can be used to examine individual measures or entire facility savings. In order to assure accuracy the model is calibrated through comparing it with facility energy consumption or end-use monitored data.

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Options A and B vs. Options C and D

The Retrofit Isolation Options: Option A or B

Addresses only the retrofitted system -

- Ignores interactive effects beyond the boundary (although these may be independently addressed)
- Usually needs a new meter

The Whole Facility Options: Option C or D

Addresses all effects in the facility -

- Retrofits AND other changes (intended and unintended)
- Often uses the utility meter

The difference is where the boundary lines are drawn

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⇩ Option A | Option B | Option C | Option D

Option A

- Simple approach (and low cost)
- Performance parameter(s) measured (before and after); usage parameters may be measured or *estimated.*
- Used where the "*potential to perform*" needs to be verified but highly accurate savings estimation is simple or not necessary.

Option A is NOT "stipulated savings" !

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⇩ Option A | Option B | Option C | Option D

Stipulate

- To stipulate is to agree to a term or condition.
- Under IPMVP, to stipulate means to *estimate without measurement*.

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Option A | Option B | Option C | Option D

Appropriate Use of Stipulations

- Parameter is well understood
- Willingness to accept risk
- Previous experience
- Probable success of ECM
- Small savings, small cost, and/or small uncertainty
- Greater M&V costs not justified
- Stipulations don't add to uncertainty
- Monitoring serves no other purpose

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Option A | Option B | Option C | Option D

Inappropriate Use of Stipulations

- Unwillingness to assume risk
- Parameters not known with reasonable certainty
- Potential for technical problems
- Monitoring provides valuable information
- Stipulation significantly contributes to overall uncertainty

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Option A | Option B | Option C | Option D

Sources of Stipulations

Acceptable	Unacceptable
• Measurements • Engineering Analysis • Measurement-based models • Manufacturer's data • Standard tables • TMY weather • ANSI/ARI/ASHRAE Facility logs	• Undocumented assumptions • Proprietary algorithms • Unsupported handshake agreements • Guesses at parameters • Models based on questionable data • Other buildings

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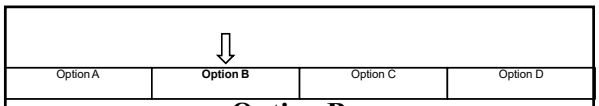

Option B

- Under Option B, all relevant parameters are measured, usually periodically or continuously.
- Measurement frequency is consistent with expected variations.
- Applicable where accurate savings estimation is necessary and where long-term performance needs to be tracked.
- Reduces uncertainty, but requires more effort.

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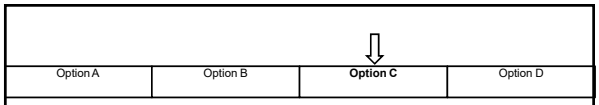

Option C

- Option C looks at energy use and cost of entire facility, not at specific equipment.
- Considers weather, occupancy, etc. for *baseline adjustments*
- Applicable where total savings need to be quantified but component-level savings do not AND where savings are > 15% of current energy use
- Easily implemented; commercial and free software is available

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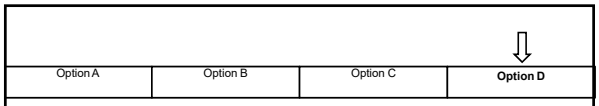

Option D

- Option D treats building as computer model
- Flexible, but requires significant effort
- Applications:
  - New construction
  - Energy management & control systems
  - Multiple interacting measures
  - Building use changes
  - Building modifications (e.g., windows)

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Option A | Option B | Option C | Option D

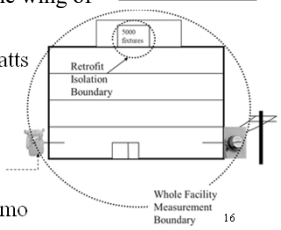
Example Lighting Project

Consider the following lighting project:

- Upgrade 5,000 fixtures in one wing of a building
- Existing performance: 86 Watts
- New performance: 56 Watts
- Operating hours: 3,000/year
- Electricity: $0.10 / kWh + $10 / kWd/mo

What's measured?

What's estimated?



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Option A | Option B | Option C | Option D

Option A

Performance:

- Baseline power consumption is 86 Watts.
- Proposed power consumption is 56 Watts.
- Difference is 30 Watts.

Usage:

- Baseline and New: 3,000 hours / year

Financial:

- Energy = $0.10/kWh + $10/kWd/mo

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Option A | Option B | Option C | Option D

Lighting Savings

- Energy Savings (ES) = QTY*(KW_{Before} - KW_{After}) * Hours
  - ES = (5,000) * (86 W - 56 W) * (3,000 hours) * (1 kW / 1000 W)
  - ES = 450,000 kWh / year

What's measured?

What's estimated?

- Demand Savings (DS) = QTY * (KW_{Before} - KW_{After}) * DF
  - DS = (5,000)*(86 W - 56 W)*(1 kW/1000 W)*DF
  - DS = 150 kW * DF
  - DF: Diversity Factor. % of lights operating when peak demand is set.

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Option A | Option B | Option C | Option D

Lighting Cost Savings

- Cost Savings = (Unit Cost)*(Energy Savings) + (Unit Cost)*(Demand Savings)

  CS = (450,000 kWh) * ($0.10/kWh) + (150 kW) * (75%) * ($10/kW) * 12 mo.
- Cost Savings = $45,000 + $13,500 = $58,500 / year
- Assumes diversity factor of 75%.

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Option A | Option B | Option C | Option D

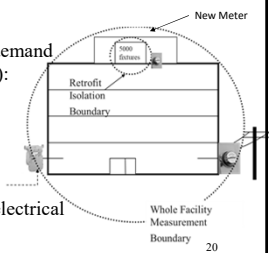
Example Lighting Project

Measurements taken at New Electric Meter

What's measured?

What's estimated?

- Pre-retrofit annual electrical usage (based on one month measurement): 2,050,000 KWh
- Pre-retrofit annual peak electrical demand (based on one month measurement): 10,100 KW
- Post Retrofit year's building electrical usage: 1,650,000 KWh
- Post Retrofit year's peak building electrical demand: 8,600 KW



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Option A | Option B | Option C | Option D

Annual Energy Savings

Energy Savings = $(KWh_{Before} - KWh_{After})$

2,050,000 – 1,650,000 = 400,000 KWh

Demand Savings = $(KW_{Before} - KW_{After})_{total}$

10,100 – 8,600 = 1,500 KW

$ Savings = 400,000 KWh x $.10/KWh + 1,500 KW x $10/KW

= $55,000

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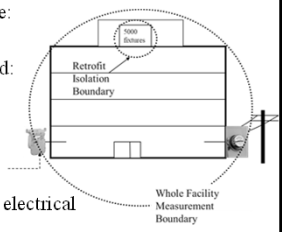
Option A | Option B | **Option C** | Option D

Example Lighting Project

Measurements taken at Building Electric Meter

- Pre-retrofit annual electrical usage:
  25,500,000 KWh (from bills)
- Pre-retrofit peak electrical demand:
  160,500 KW (from bills)
- Post Retrofit one year building electrical usage:
  25,600,000 KWh
- Post Retrofit year's total building electrical demand:
  160,600 KW



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Option A | Option B | **Option C** | Option D

Annual Energy Savings

Energy Savings = $(KWh_{Before} - KWh_{After})$

25,500,000 – 25,600,000 = -100,000 KWh

Demand Savings = $(KW_{Before} - KW_{After})_{total}$

160,500 – 160,600 = -100 KW

$ Savings = -100,000 KWh x $.10/KWh + -100 KW x $10/KW

= ($11,000)

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Option A | Option B | Option C | **Option D**

Example Lighting Project

Pre-retrofit Measurements taken at Building Electric Meter

- Incorporate lighting modifications by computer modeling building.
- Baseline is existing building before lighting modifications.

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Option A | Option B | Option C | **Option D**

Develop Computer Model...

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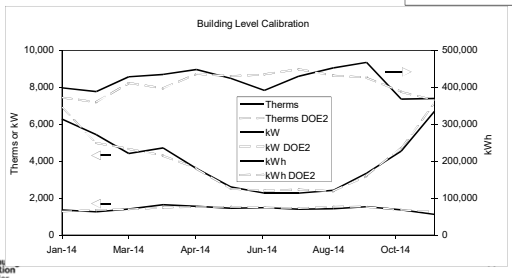
Option A | Option B | Option C | **Option D**

... Calibrate Model ...

What's measured?

What's estimated?



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Option A | Option B | Option C | **Option D**

... and Evaluate Results

What's measured?

What's estimated?

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Option A | Option B | Option C | **Option D**

Calculate Savings

Evaluate energy use for lighting retrofit.

Calculate savings relative to base case.

	Energy Use, kWh Demand, kW			
Alternative	**Lights**	**Cooling**	**Other**	**Total KWh Coincident Load, KW**
Base Case	15,500,298 5,167	5,955,263 2,382	4,935,729 1,652	26,391,290 9,201
Lighting Retrofit	15,125,240 4,950	5,860,062 1,953	5,005,638 1,667	25,990,940 8,570

Energy Savings = $(KWh_{Before} - KWh_{After})$ 26,391,290 – 25,990,940 = 400,350 KWh

Demand Savings = $(KW_{Before} - KW_{After})_{total}$ 9,201 – 8,570 = 631 KW

$ Savings = 400,350 KWh x $.10/KWh + 631 KW x $10/KW = $46,345

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Option A | Option B | Option C | **Option D**

Comparison of Options

Option	Energy Savings as % of Total within Boundary	Cost Savings
A	34.8%	$58,500
B	19.5%	$55,000
C	1.6%	($11,000)
D	1.7%	$46,345

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Review and Discussion

- Total energy use and savings are functions of both usage and performance.
- Options A and B are retrofit-isolation methods.
- Options C and D are whole-facility methods.
- Can mix and match methods.
- Selection of M&V method based on need to verify savings cost-effectively.

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GROUP DISCUSSION

WHAT OPTION SHOULD BE USED FOR EACH OF THESE PROJECTS?

- Convert building from electric heat to hydronic gas-fired condensing hot water system
- Install 1.5 MW solar photovoltaic system on building roof
- Campus wide replacement of steam traps
- Construct LEED platinum building in lieu of LEED silver

Option A: "Retrofit Isolation, Key Parameter" – Based on *measured* equipment performance, measured or *estimated* operational factors, and annual verification of "*potential to perform.*"

Option B: "Retrofit Isolation, All Parameters" – Based on *measurements* (usually *periodic or continuous*) taken of all relevant parameters.

Option C: Based on *whole-building* or facility-level utility meter data adjusted for weather and/or other factors.

Option D: Based on *computer simulation* of building or process; simulation is calibrated with measured data.

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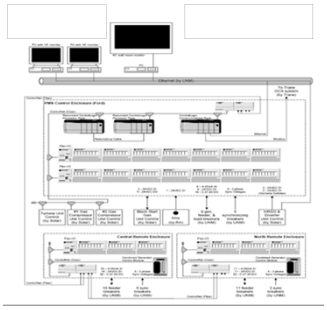
Questions & Answers

Thank You!



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This concludes The American Institute of Architects Continuing Education Systems Course

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